Leaf Size Variation at Cook's Woods

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Introduction

The relationship between leaf form and climate has been studied by ecologists (1, 2, 20, 25, 30) and paleobotanists (9, 30, 31, 32) for many years. Their studies have been concerned with two specific characters, average leaf size and leaf margin type. In 1915, Bailey and Sinnott (1, 2) postulated that leaf margin type and mean annual temperature were directly correlated. As temperature decreases, either with increasing altitude or decreasing latitude, the percentage of species having leaves with entire margins in a flora also decreases (1, 2). The only exceptions occur in physiologically dry areas, such as deserts, where the percentage of species having leaves with entire margins is always high, regardless of altitudinal or latitudinal position. Recent studies (31, 32, 33) using both modern and fossil floras have tended to substantiate these conclusions (1, 2). Raunkiaer (25) postulated that leaf size was directly correlated with mean annual precipitation. As mean annual precipitation decreases, the percentage of species having large leaves in a flora also decreases (25). Very little field work (9) has been carried out to validate this hypothesis.

Recently, ecologists have begun to mathematically model the relationship between leaf form and climate. For example, Givnish (20) postulates that optimal leaf size, as determined by the balance between transpiration, root costs, and photosynthesis, should be greatest in the tropics, decrease into the subtropics, increase into the temperate region, and finally decrease toward the poles. Although his (20) approach has provided significant new insights into the relationship between leaf form and climate, the results are only indirectly correlated with typical climatic variables such as temperature and precipitation. No distinction is made between altitudinal and latitudinal trends.

The majority of studies that have been carried out have attempted to correlate the leaf characteristics of broad regional floras with the general climate for the areas in which they live. Only recently have studies been undertaken attempting to relate leaf form and climate at the local level (16, 17, 18, 19). Most of these studies have been confined to the tropics (16, 17, 18). The results indicate that leaf margin type is not closely correlated with climate at the local level (16, 19). In contrast, leaf size is correlated with climate, at least to the extent that four foliar belts can be recognized in the tropical latitudinal region of the Western Hemisphere (14, 17, 18). Attempts to extend these foliar belts into the subtropical and warm temperate latitudinal regions have failed due to a lack of data (14). In this paper, the leaf size variation at Cook's Woods is analyzed and compared with other data available from the warm temperate latitudinal region of the Western Hemisphere.

Materials and Methods

Cook's Woods, located north of the Mississinewa Reservoir in Miami County, Indiana (Sec. 34, T 27 N, R 5 E, Peoria Indiana Quadrangle) was chosen as the site for this study (Fig. 1). An analysis for stand disturbance (26) indicated that Cook's Woods is a secondary successional forest. Two parallel line transects were run along the ridge top at the site. Each transect was 400 m long. Importance values for the dominant species in the canopy and understory were determined using the point-centered quarter method (11, 12, 24). The sampling points were located at 20 m intervals along the transects. The

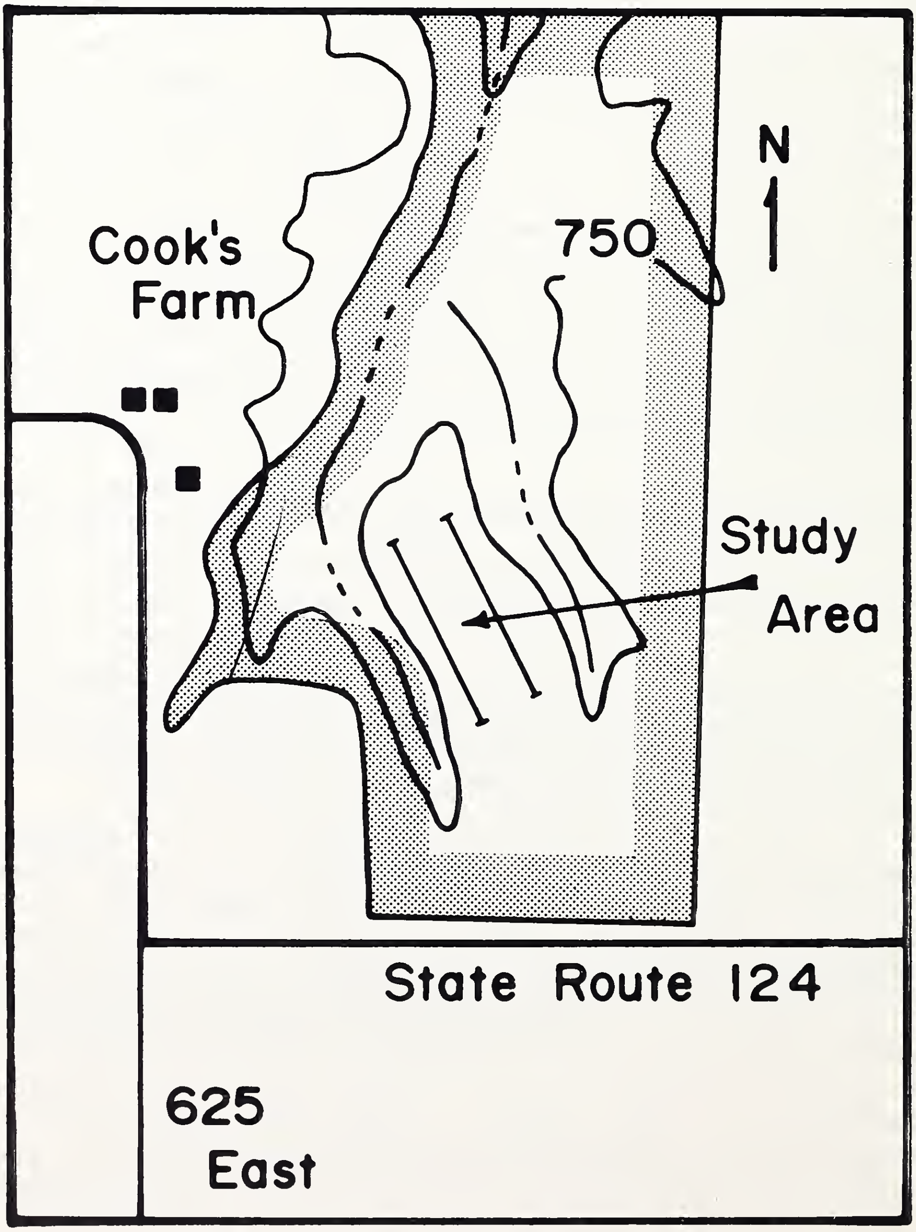

FIGURE 1. *Location of the study area in Cook's Woods.*

dominant species in the shrub layer were studied using 10 quadrants located at 20 m intervals. Each quadrant was 100 m square. The importance value for each species encountered (Table I) was calculated using the method of Curtis and McIntosh (5, 6).

TABLE I *Importance values and average leaf areas of the woody, dicotyledonous trees, shrubs, and vines found at Cook's Woods. The species were identified using Deam (7, 8).*

Species	Importance Value (Canopy and Understory)	Importance Value (Shrub Layer)	Leaf Size
Carya glabra	116.3		30.6
Acer saccharum	33.1	59.8	63.5
Ostrya virginiana	26.5	60.7	19.3
Carpinus caroliniana	25.2		21.8
Carya ovata	24.2		34.7
Quercus alba	21.8	21.4	69.9
Fagus grandifolia	10.1	10.3	35.7
Liriodendron tulipifera	9.0	1.5	124.8
Quercus rubra	8.7		58.9
Prunus serotina	7.8	20.0	22.7
Crataegus punctata	5.4	22.3	10.5
Populus grandidentata	2.5		36.3
Ulmus rubra	2.5	38.7	51.2
Quercus mühlenbergii	2.0		70.9
Morus rubra	1.8	9.0	89.4
Cornus florida	1.6	3.7	35.1
Celtis occidentalis	1.6		40.5
Juniperus virginiana		1.2	——
Viburnum acerifolium		2.7	39.8
Asimina triloba		3.3	118.0
Cornus alternifolia		2.7	24.0
Fraxinus americana		16.9	30.2
Diervilla lonicera		6.4	10.7
Lindera benzoin		16.8	37.1
Ribes cynosbati		2.5	12.0
Rubus occidentalis			19.7
Sambucus canadensis			21.8
Gleditsia triacanthos			2.0
Euonymus atropurpureus			30.9
Rubus flagellaris			24.4
Platanus occidentalis			144.2
Parthenocissus quinquefolia			36.8
Vitis sp.			74.1
Carya cordiformis			59.4
Tilia americana			91.7

The average leaf area was calculated for every species of woody, dicotyledonous tree, shrub, and vine encountered along the line transects as well as for several additional species encountered while walking through the woods. The area of 50 leaves from each species encountered was determined using a dot planimeter (13, 21). The average leaf area for each species (Table I) was calculated using a modified version of a computer program provided by Sokal and Rohlf (27).

To facilitate the comparison of the results obtained in this study with those from other localities both in the temperate zone (3, 10, 30) and in the tropics (14, 17, 18), the percentage of species having large leaves (greater than 20.25 sq cm in area, *sensu* 9) at each locality was plotted on a modified version of Holdridge's (22, 23) life zone chart (Fig. 2). The chart was modified to show only the warm temperate life zones from which data were available. Each locality was plotted on the life zone chart using climate data from the U.S. Department of Commerce Environmental Data Service (28, 29).

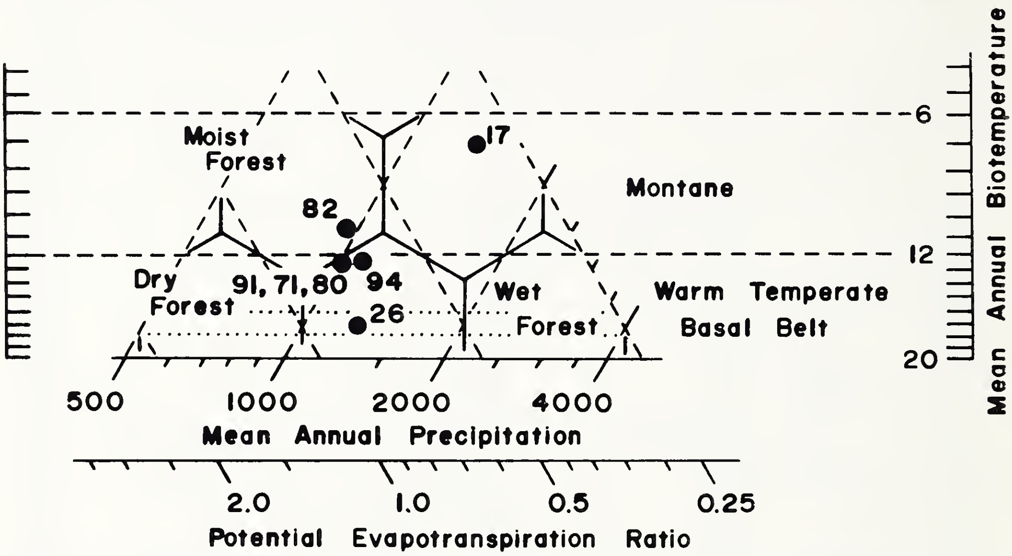

FIGURE 2. *Variation in leaf size at the seven sample sites that have been studied in the Western Hemisphere (see text for details of chart construction).*

Results and Discussion

The species with the highest importance value at Cook's Woods is *Carya glabra* (I.V. = 116.3, Table I). No other species in the canopy and understory had an importance value approaching that of *C. glabra.* The shrub layer is dominated by seedlings of *Acer saccharum, Ulmus rubra, Ostrya,* and *Carpinus* (Table I). The lack of any clear dominants at Cook's Woods is an indication of the secondary nature of the forest. Based on comparisons carried out between virgin and secondary tropical forests (15), it is doubtful that the successional nature of Cook's Woods would affect the results of this study. The analysis of leaf size variation is dependent on the species present and not the structure of the mature vegetation (15).

The percentage of species having large leaves (*sensu* 9) at Cook's Woods was 82.4%. This percentage compares favorably with the percentages found at other localities in the lowland temperate forests of North America. One other site (Fig. 2) has been studied in Indiana (10, 13). The percentage of species having large leaves at Cedar Bluffs, Indiana, was 94.4% (10, 13). Three localities (Fig. 2) were analyzed in the Cincinnati area (30). The percentages of species having large leaves at these sites were 90.9% (mesophytic climax forest), 71.1% (upland forest), and 80.0% (grassland).

All of these values compare favorably with the average percentage of species having large leaves in the first foliar belt of the tropical lowlands of the

Western Hemisphere (83.0%, 14). The high percentage of species having large leaves in warm temperate forests as well as the correspondence in leaf size between these forests and those of the tropics were pointed out by Givinish (20). These conclusions are significantly different from those reached by Raunkiaer (25). However, complete agreement with the theory of Givnish (20) was not found. In the Smoky Mountains, the percentage of species having large leaves decreases with increasing altitude. Only 16.7% of the species in the heath balds on Mt. LeConte had large leaves (3). At one warm temperate locality in southern Brazil (the temperate gallery forest at Horto Botânico), the percentage of species having large leaves was 25.7% (4). These percentages agree with the predictions of Raunkiaer (25) and not of Givnish (20). Based on the data available, there is insufficient information to choose between these two theories (20, 25). Further field research will have to be carried out before a definite correlation between leaf size and climate can be proven.

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